The use of geosynthetic materials in special engineering geological conditions of the Far East

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ABSTRACT: The design of a variable hardness is developed for preventing deformations in the line facilities built on sections with different stability. The results of geotechnical modeling are presented with the example of federal Vladivostok-Nakhodka road. This highway is constructed in the harsh environments and complex engineering-geological conditions on seasonal freezing soils. The sections with different stability are located there. The design includes installation of geosynthetic material layers. The amount and location of the geogrid layers depends on the base stiffness. The structural behavior modeling with the geotechnical software complex «FEM models» gives a design assessment. Some constructional measures are taken as a result of the modeling to provide an exploitation reliability of the highway engineering solutions

Keywords: deformations, geotechnical modeling, geosynthetic material

1 INTRODUCTION

The building of constructions in northern regions of the Far East is always connected with a high degree of seasonal freezing risk. This especially refers to a line transport structures which require a high level of reliability and responsibility as seen in studies [1,2]

As researches show [3-6] one of the rational solutions for the main issues which is connected with a construction of facilities in the areas with complex geological and climatic conditions is reasonable usage of modern geosynthetic material properties.

Such materials are capable of providing long-term stable operation of facilities made of local building materials. This can be seen in the works [7-9]. So, the properties of such geosynthetics materials must fully comply with the demands of conditions of their work in the structures and provide a long lifespan as well as high quality as dis-cussed in the study [10].

The problem of a sufficiently short section is the combination of different stiffness. Part of the section on the left side has a pile foundation that is not subject to a large draft.

The right part of the section is located entirely on the weak base. Having reviewed the works [11,12] additional structural element has been developed to ensure a smooth transition from one construction to another. It has variable stiffness on the entire length of a weak base. The element of variable stiffness is arranged at the top of the embankment across the all width of a passage connecting the junction area of constructions with different stiffness.

This element provides a variable stiffness in the longitudinal direction as it is made of integral biaxial geogrid meshes. The biaxial geogrid E'GRID 4040L is placed at the different levels with crushed stone of 40-70 mm fraction. All the major elements of the variable stiffness design are shown in Figures 1-3.

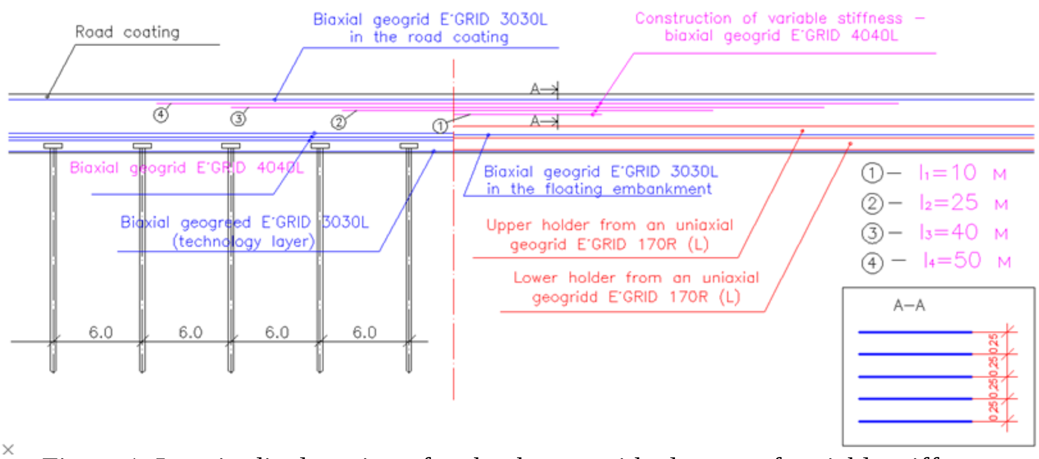

Figure 1. Longitudinal section of embankment with element of variable stiffness.

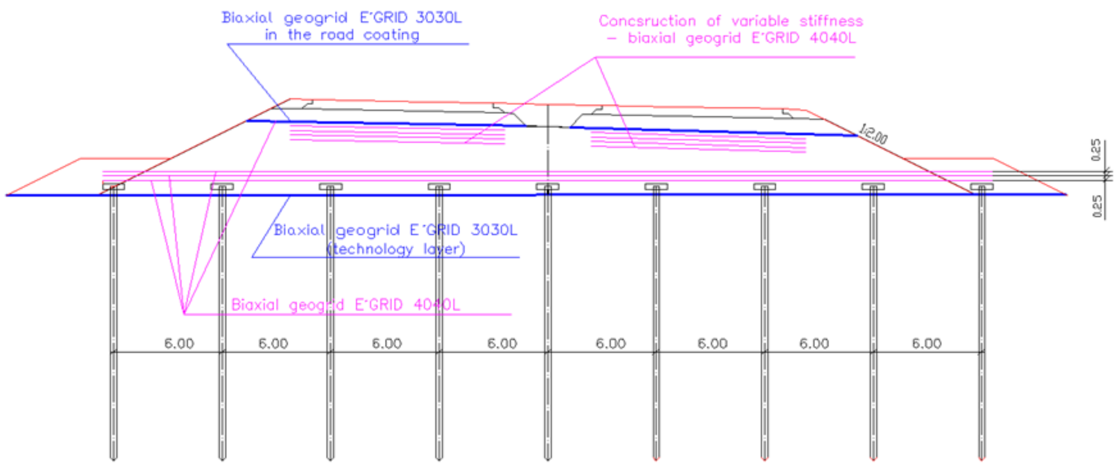

Figure 2. Variable stiffness design in the zone of pile foundation.

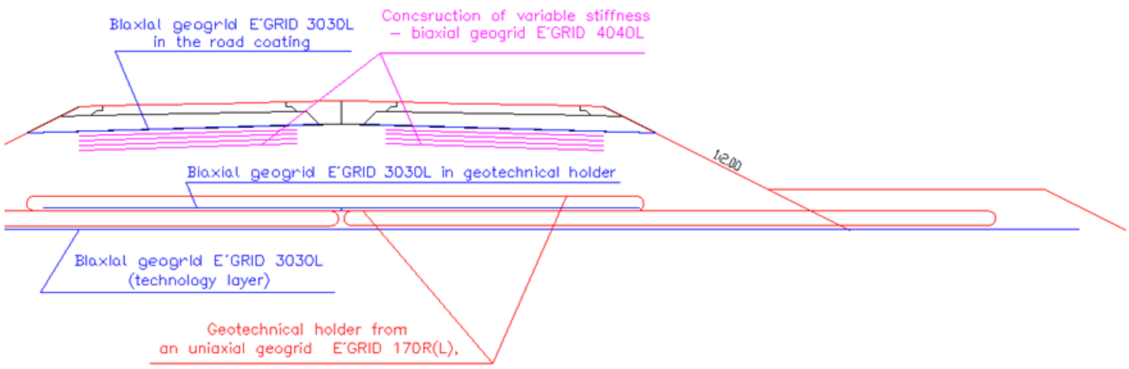

Figure 3. Variable stiffness design in the zone of the weak base.

2 METHODS OF NUMERICAL MODELING

As discussed in the works [13-15], it is necessary to perform a calculation.

The design geotechnical modeling was performed using software package «FEM models», which was developed by geotechnical engineers from Saint-Petersburg.

The elastic-plastic model with the yield criterion was used to describe the work of variable stiffness design. This elastic-plastic model was chosen because its parameters can be taken from existing material of engineering and geological surveys.

Numerical methods are in good correspondence with the traditional engineering methods of calculating the settlement in such formulation. They provide accurate description of deformations in structures.

Figure 4 shows a scheme of determining the theoretical stresses in the elastic-plastic model of the soil.

The ultimate stresses in the tension field are restricted by the tensile strength σp.
Area I in the tension field is restricted by the stress σ3=σp, while in the compression area it is restricted by the Coulomb strength criterion according to:

$$\sigma_1 = R_c + \sigma_3 ctg\psi \quad (1)$$

where Rc is the uniaxial compression strength.

The element stiffness matrixes and the ones for the whole system are formed once and stay the same in the procedure of elastic-plastic solution. The load is applied in small portions as it happens in its real sequence in nature.

If the point M occurs within the limits of the elastic region I, it means the element is in the elastic state and there is no need to correct the stresses.

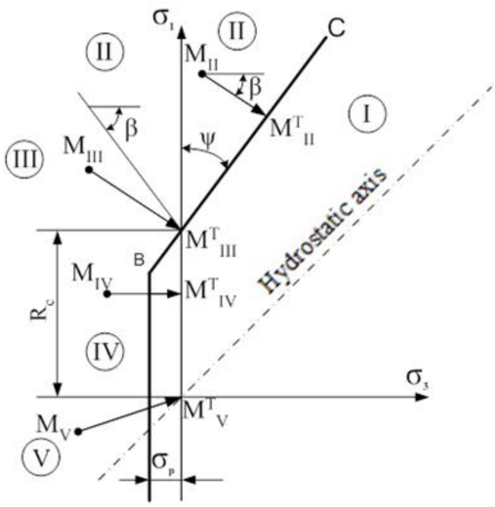

Figure 4. Scheme of determining theoretical stresses in elastic-plastic model of soil.

If the point M occurs beyond the yield behavior contour, the theoretical stresses are calculated in the following order. If the point of total stress occurs in the area II (the basic plastic zone), the theoretical point lies at the intersection of the plastic yield and the right line.

If the point of total strength occurs in area III, the element breaks in the direction of the stress, while the stresses go down to the level of the soil strength to the uniaxial compression.

For the area IV where the stresses do not go beyond the uniaxial compression strength, the parameters are the following. Finally, for the area V where the element is broken, the parameters are the following:

In the FEM Models program the natural stress state is substituted by the hydro engineering tensor for pressing the soil of the "characteristic volume" that is summarized with the actual stresses in situ:

$$\{\sigma_{1,3}\} = \{\sigma_1{}^F{}_{,3}\} + \{\sigma_1{}^G{}_{,3}\} \quad (1)$$

The assumption reflects a real picture of the natural stress state in weak soils.

The used method and the software package «FEM models» are developed by the authors for the projects under construction in Russia and the Far East.

Application of the methods and approaches for the calculation and design of geotechnical structures using software package «FEM models» show its accurate and objective performance in the most rational calculations of geotechnical constructions. This can be seen from the works [16-19].

3 RESULTS OF NUMERICAL SIMULATION

On the basis of numerical modeling the close to real picture of the vertical defor-mation for the variable stiffness design is obtained.

The numerical models of the design of variable stiffness on the Vladivostok-Nakhodka road section are shown in Figures 5 – 7.

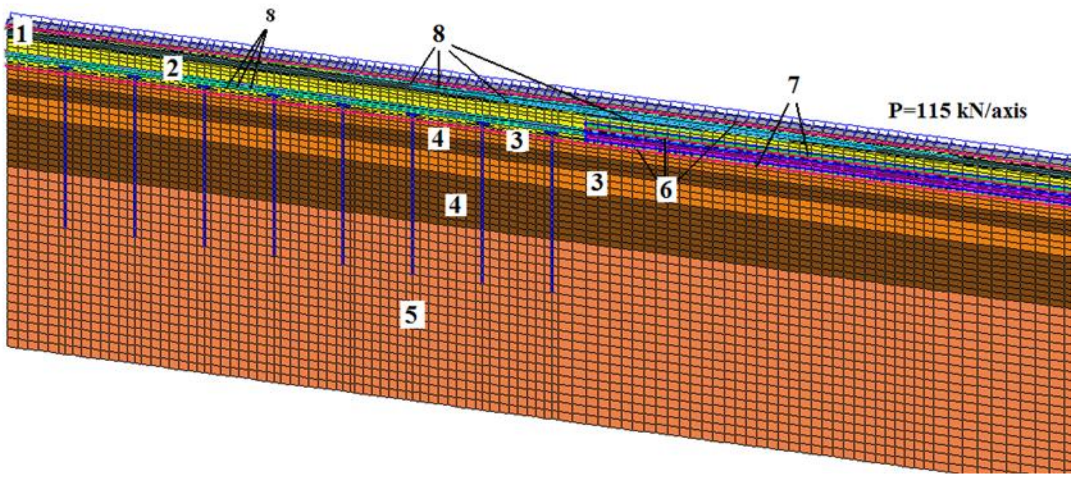

Figure 5. Numerical model: 1 – pavement; 2 - crushed stone; 3 – silty sandy loam; 4 – silt loam; 5 – pebble; 6 – biaxial geogrid E´GRID 3030L; 7 – geotechnical holder from uniaxial geogrid E´GRID 170R(L) ; 8 – biaxial geogrid E´GRID 4040L.

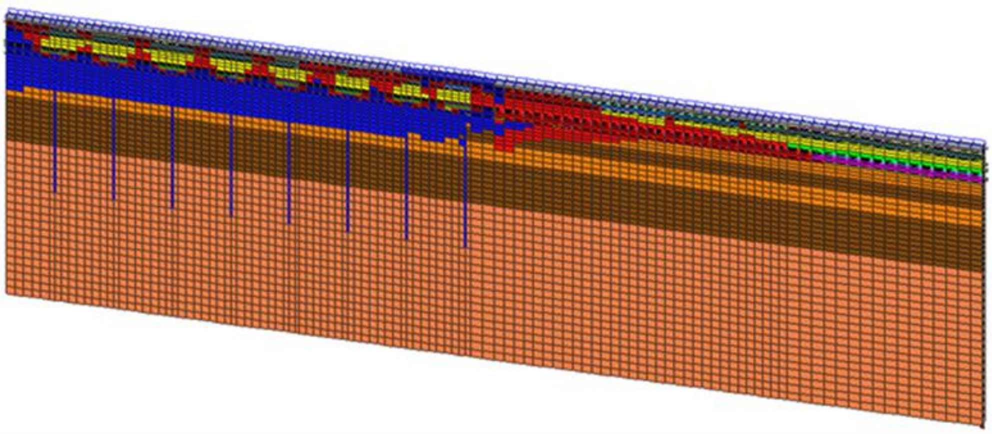

Figure 6. Zones of elastic and plastic deformations: blue color – elastic deformations; red color - plastic deformations.

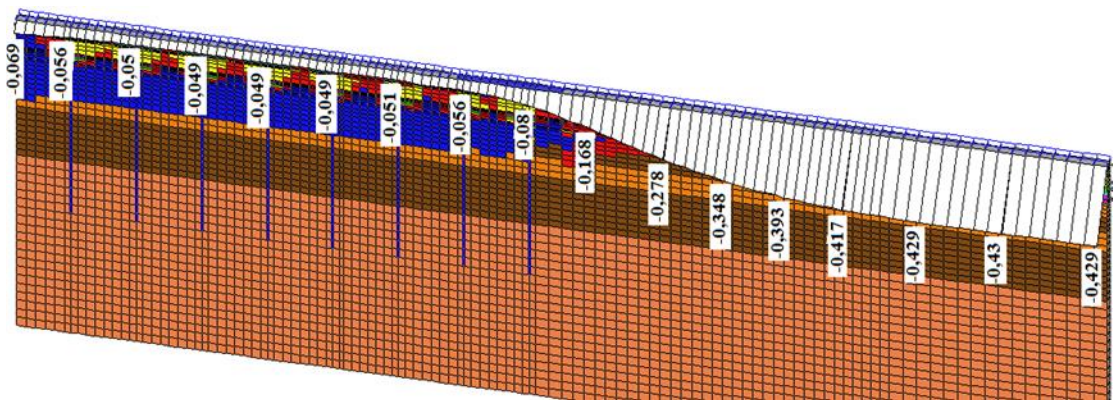

Figure 7. Curve of vertical deformation on construction surface of with variable stiffness design, m.

4 CONCLUSIONS

1. The results of the numerical simulation of structures with element of variable hard-ness showed a smooth change in hardness at the surface facilities
2. This element avoids sharp deformations of road
3. Smooth change of hardness provides normative technical condition of road during using it in places of sharp changing in stiffness of adjacent structures
4. High strength of construction with elements of geosynthetic materials ensures the integrity of the road as well as the safe use of this section of the road
5. All this technical solutions have theoretical and laboratory proofs, as well as exten-sive experience of the practical application for strengthening roadbed and for a weak base with the use of modern high-tech geosynthetics materials.

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